

LABORATORY ASSESSMENT OF VACUUM-BASED CRACK MONITORING SENSOR



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OUTLINE

- **Background**
- **Similar Technologies**
- **Technology Description**
- **Testing**
- **Test Results**
- **Current Status of CVM Technology**
- **Conclusions/Recommendations**



BACKGROUND

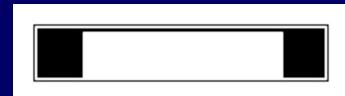
- AFRL was introduced to novel crack detection technology - Comparative Vacuum Monitoring (CVM™)
 - Developed by Structural Monitoring Systems (SMS) based in Australia
 - Nondestructive Evaluation (NDE) Team had interest in technology and an immediate need for real time crack detection monitoring
- Agreement was made for use of equipment in exchange for an informal assessment



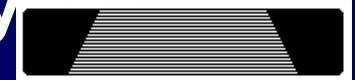
SIMILAR TECHNOLOGIES

- Other crack detection/monitoring technologies:

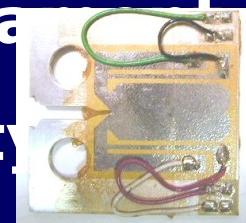
- Crack Detection Gage (filament-type)



- Crack Propagation Gage (filament-type)



- Crack Detection Gage (foil-type)



- Electro-Potential Difference



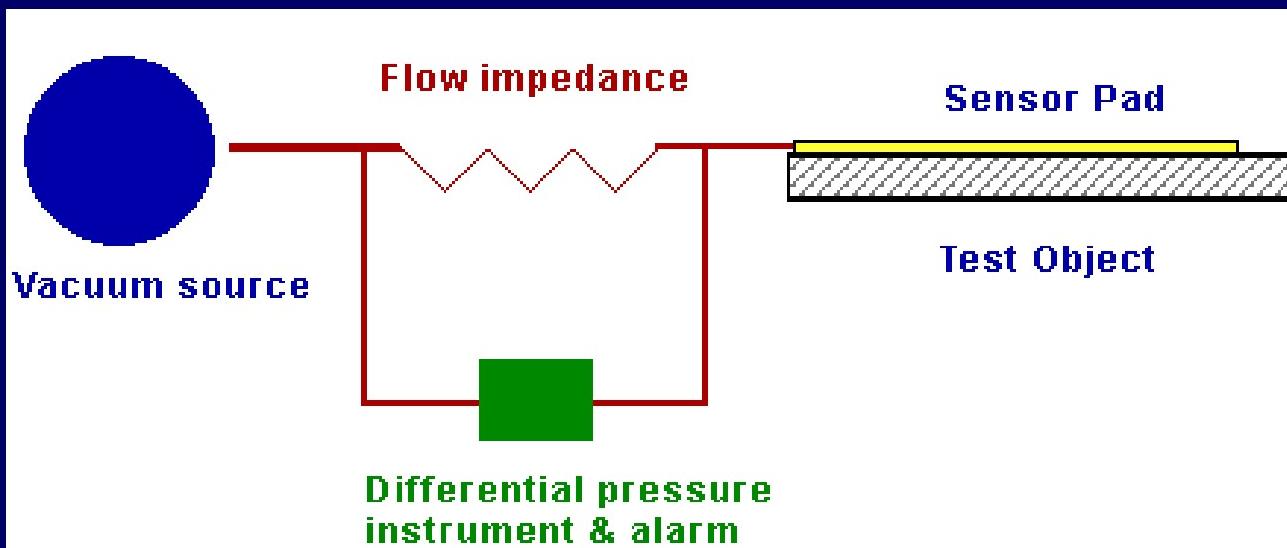
Test
Leads

Test
Article



TECHNOLOGY DESCRIPTION

- **CVM Concept:**
 - Small volume under vacuum
 - Measure air ingress caused by leak (surface crack)



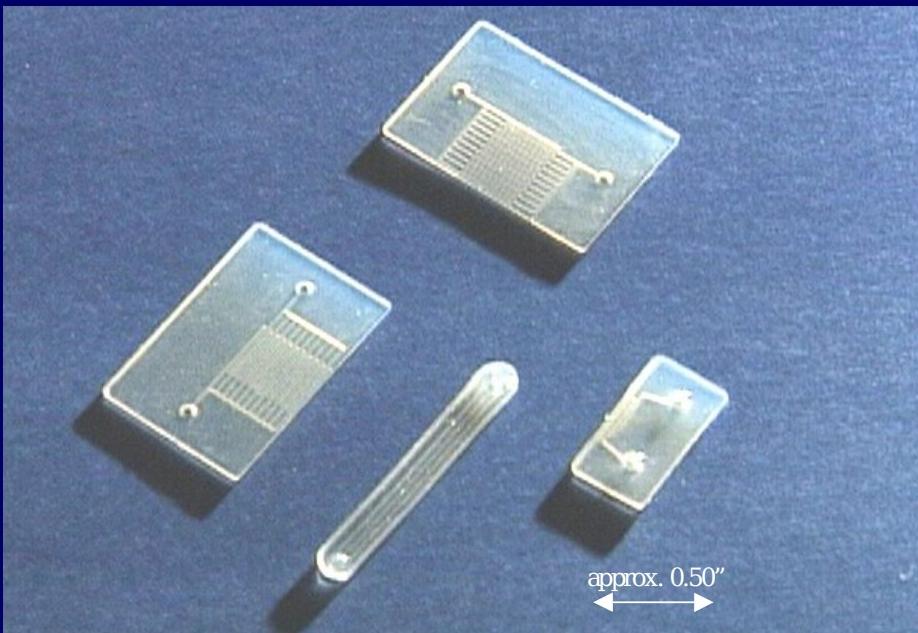
System schematic



TECHNOLOGY DESCRIPTION



- **Sensor Pad**
 - **Self adhesive, flexible polymer**
 - **Channels molded on one surface**



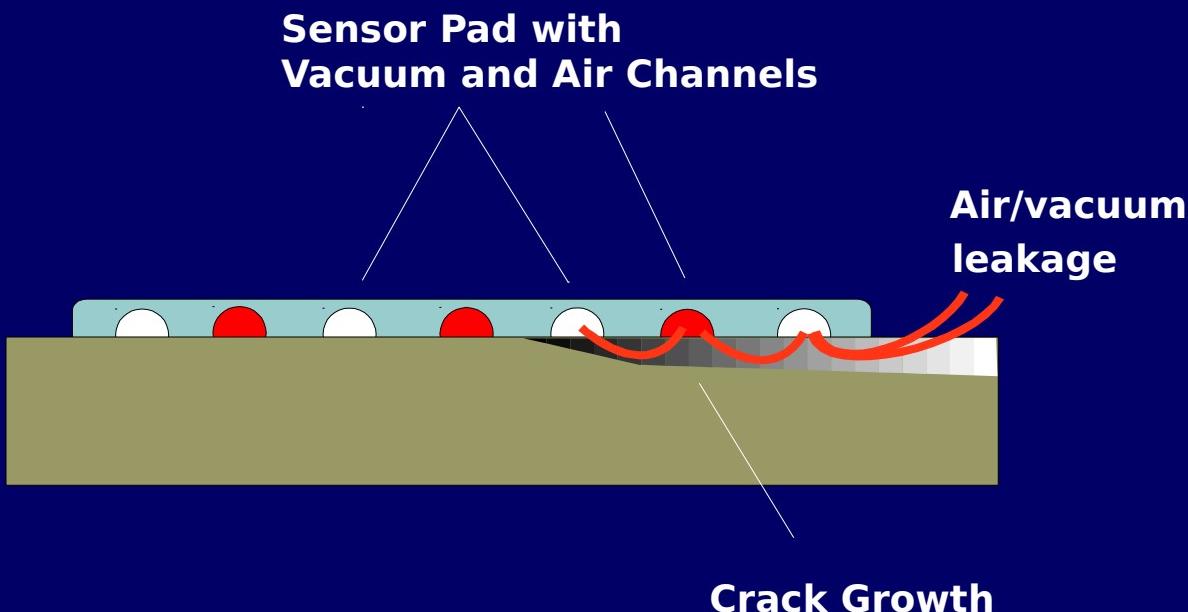
Typical sensor pads



TECHNOLOGY DESCRIPTION



- Sensor Pad
 - Crack growth beneath pad is detected when “vacuum gallery” is opened to atmospheric pressure

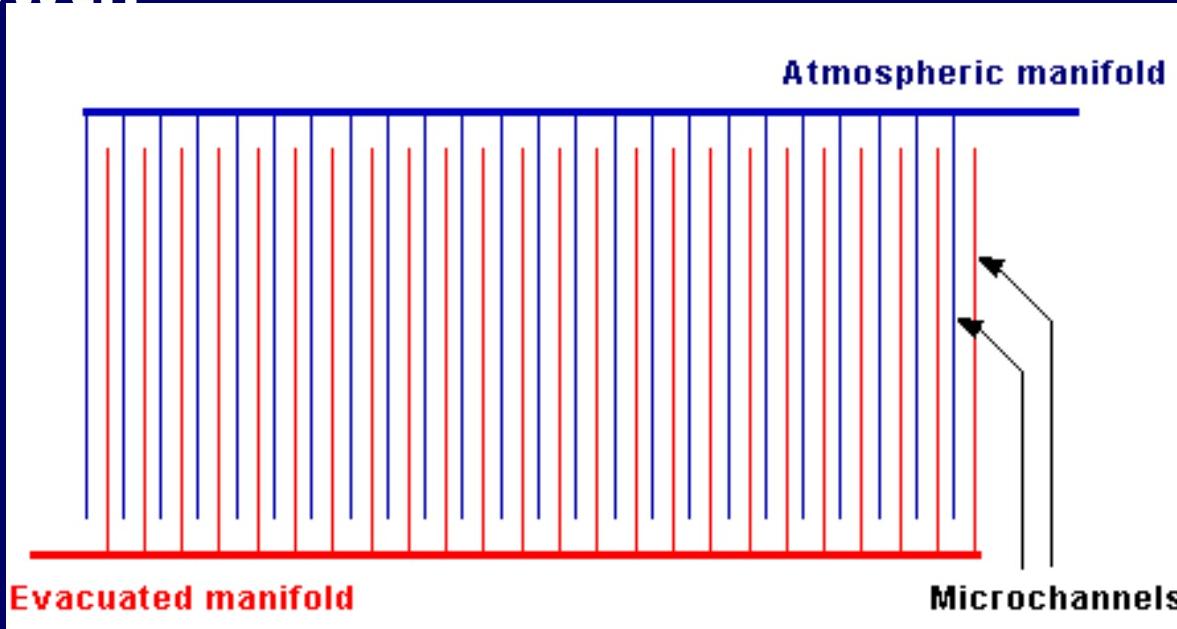




TECHNOLOGY DESCRIPTION



- Sensor Pad
 - Configured for crack detection or crack growth



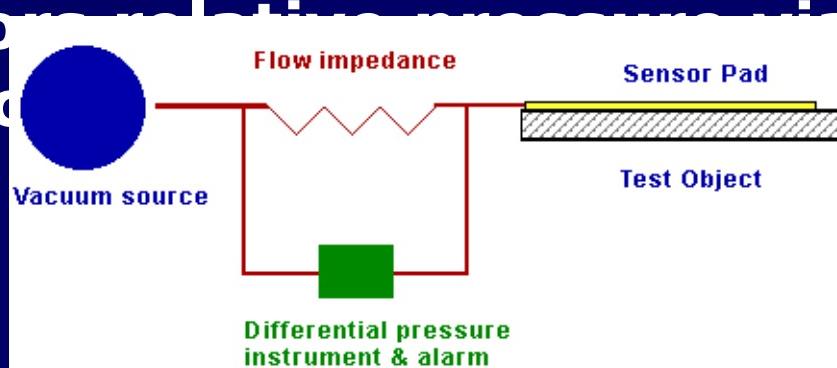
Sensor pad schematic for crack detection



TECHNOLOGY DESCRIPTION



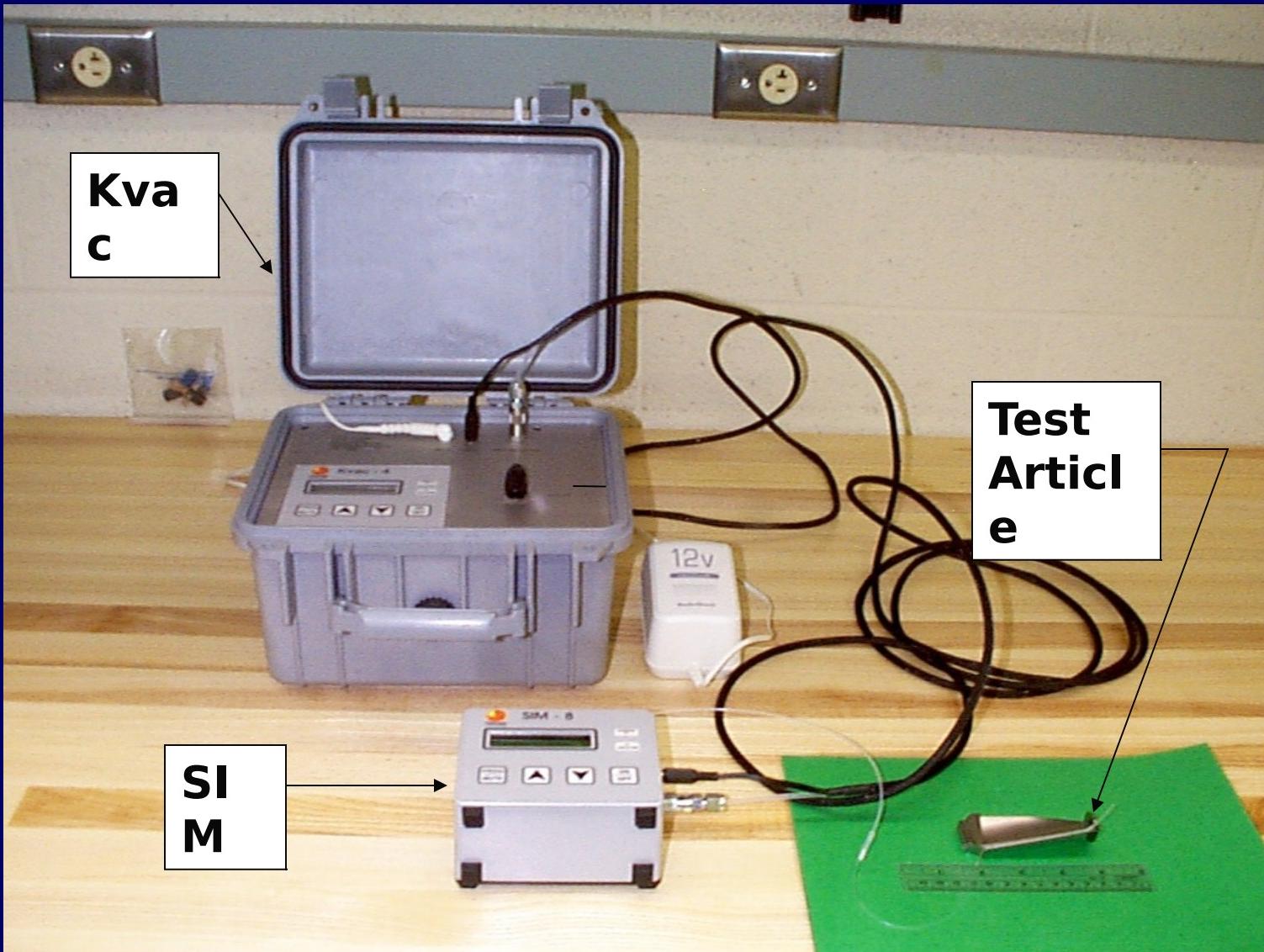
- System Equipment:
 - Kvac (constant vacuum source)
 - Pulls vacuum on sensor pad
 - Reference for relative pressure measurement
 - SIM (flow sensing device)
 - Monitors relative pressure in low conductive media



System schematic



TECHNOLOGY DESCRIPTION





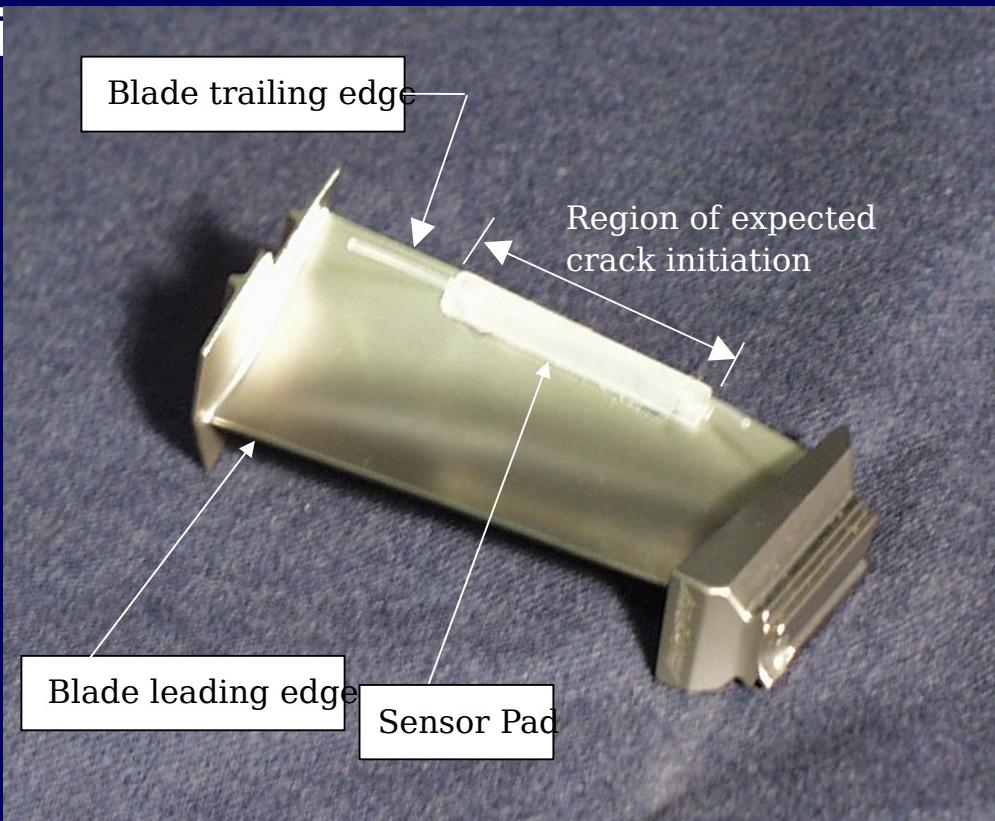
TESTING

- Primary purpose:
 - Grow natural cracks in engine turbine blades
 - 0.020 - 0.080" **WITHOUT** starter notches
- Secondary purpose:
 - Evaluate novel vacuum-based sensor for lab applications



TESTING

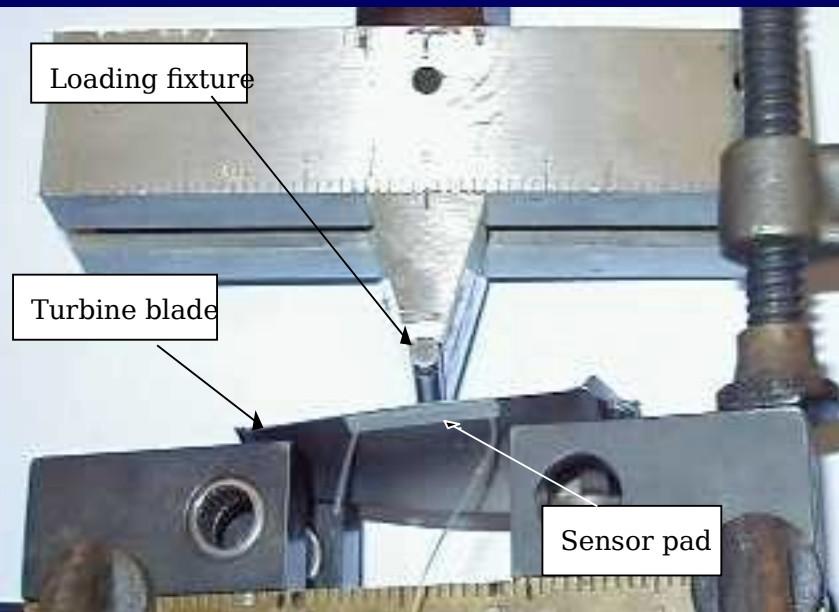
- **Test Article**
 - **Inconel 713 turbine blade**
 - **Edge crack desired perpendicular to trailing edge**





TESTING

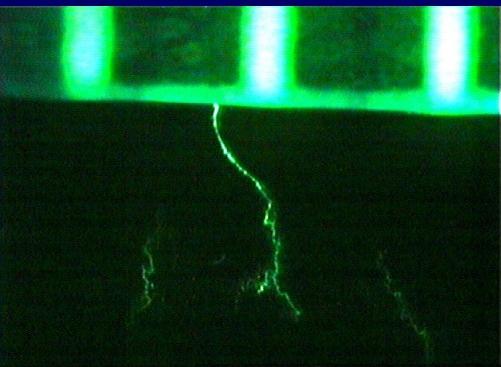
- Test Approach
 - AFRL/MLSC Structural Test Facility
 - 3 point cyclic bending
 - 10 Hz, increase load every 10000 cycles



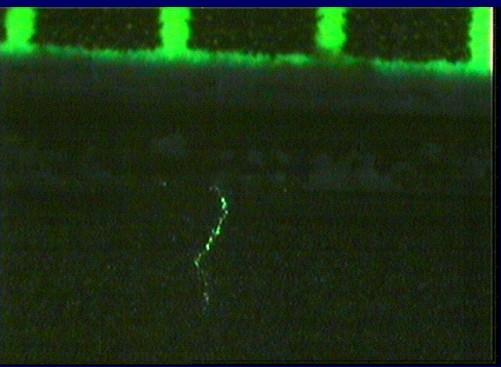
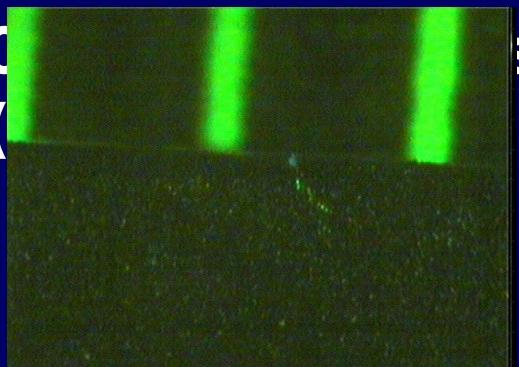


TEST RESULTS

- Natural cracks detected in two blades
 - 0.047" convex side/0.077" concave



- 0.047" convex side/0.077" concave





CURRENT STATUS OF CVM TECHNOLOGY



- **Failure Modes and Effects Analysis**
 - Risks being examined for on-aircraft installation
- **Independent tests of sensor and adhesive constituents**
 - Neutral pH
 - Negligible mobile ions
- **Performance through paint evaluated**
 - Able to detect cracks through various thicknesses and ages of paint systems (note: paint cracked)
- **Effect of long vacuum ducting evaluated**
 - Sensitivity is governed by gallery spacing



CURRENT STATUS OF CVM TECHNOLOGY



- Portable in-field unit evaluation - IN WORK
- Validation trials on flying aircraft - IN WORK
- Long-term environmental program - PLANNED
 - Temperature and humidity extremes
 - Chemical and UV exposure
 - Sensors will be overcoated with sealant



CONCLUSIONS/ RECOMMENDATIONS



- Crack growth on turbine blade without starter notch proved challenging
 - Experimental test method - trial & error approach
 - Unpredictable crack growth rates
 - Dependent on test operator to stop test once crack detected



CONCLUSIONS/ RECOMMENDATIONS



- CVM is an effective alternative means for surface crack detection in a lab environment
 - 0.020" sensitivity possible
 - User-friendly operation
 - Adheres with minimal surface prep
 - Complex geometry applications
- On-aircraft applications need further evaluation